

**WHAT IS CLAIMED IS:**

1. A gel polymer electrolyte for rechargeable batteries comprising (i) a gel polymer which is the reaction product of (A) an amine-group containing material, and (B) a halide-group or epoxy-group containing material, and (ii) a liquid electrolyte which contains an amount of an ionic salt effective to achieve ionic conductivity of about  $1 \times 10^{-2}$  S/cm or less.
2. The gel polymer electrolyte as in claim 1, wherein the gel polymer is the reaction product of a nitrogen-group containing material (A) and a halide-group or epoxy-group containing material (B).
3. The gel polymer electrolyte as in claim 2, wherein the halide-group containing material includes at least one halide group selected from chlorides, bromides and iodides.
4. The gel polymer electrolyte as in claim 2, wherein the epoxy-group containing material includes at least one monomer, oligomer or polymer having at least one epoxy unit.
5. The gel polymer electrolyte as in claim 1, wherein the ionic salt is a lithium salt.
6. The gel polymer as in claim 5, wherein the lithium salt is at least one selected from the group consisting of  $\text{LiPF}_6$ ,  $\text{LiAsF}_6$ ,  $\text{LiClO}_4$ ,  $\text{LiN}(\text{CF}_3\text{SO}_2)_2$ ,  $\text{LiBF}_4$ ,  $\text{LiCF}_3\text{SO}_3$  and  $\text{LiSbF}_6$ .

7. The gel polymer as in claim 1, wherein the ionic salt is present in an amount effective to achieve an ionic conductivity of between about  $1 \times 10^{-3}$  to about  $1 \times 10^{-2}$  S/cm.

8. The gel polymer as in claim 1, wherein the nitrogen-group containing material (A) includes at least one secondary or tertiary amine selected from polymers, copolymers, oligomers and monomers containing 6- membered aromatic heterocycles, 5-membered fused aromatic heterocycles and aromatic or non-aromatic tertiary amine compounds.

9. The gel polymer as in claim 8, wherein the material (A) includes at least one compound selected from the group consisting of pyridines, pyridazines, pyrimidines, pyrazines, triazines, triazoles, thiazoles, thiadiazoles, and compounds containing five or more carbon atoms in addition to at least one nitrogen atom.

10. The gel polymer as in claim 1 or 9, wherein material (B) includes an epoxy-group containing material and/or material (B) includes an epoxy-group containing material and/or a an aromatic or non-aromatic halide material an aromatic or non-aromatic halide material.

11. The gel polymer as in claim 10, wherein the material (B) is an aromatic halide selected from polymers, copolymers or monomers containing halomethyl benzene, halomethyl naphthalene, halomethyl biphenyl, bis(halomethyl) benzene, bis(halomethyl) naphthalene, bis(halomethyl) biphenyl, tris(halomethyl) benzene, tris(halomethyl) naphthalene, tris(halomethyl) biphenyl, tetrakis(halomethyl) benzene, tetrakis(halomethyl) naphthalene, tetrakis(halomethyl) biphenyl, halomethylstyrene.

12. The gel polymer of claim 11, wherein the halomethyl of the aromatic halide is chloromethyl, bromomethyl or iodomethyl.

13. The gel polymer of claim 10, wherein the material (B) is a non-aromatic halide selected from C2 or greater alkanes which include diiodo, triiodo or tetraiodo groups.

14. The gel polymer as in claim 10, wherein material (B) is an epoxy-group containing material which is at least one selected from the group consisting of 3,4-epoxycyclohexylmethyl-3',4'-epoxycyclohexane carboxylate, glycidyl dodecafluoroheptylether, polypropylene glycol diglycidyl ether, glycidyl dodecafluoroheptylether, butadiene diepoxide, butanediol diglycidyl ether, cyclo hexene oxide, cyclopentene oxide, diepoxy cyclooctane, ethylene glycol diglycidyl ether and 1,2-epoxy hexane.

15. The gel polymer electrolyte of claim 1, wherein the gel polymer is present in an amount between about 1 wt.% to about 30 wt.%.

16. The gel polymer electrolyte of claim 1 or 15, wherein the liquid electrolyte is present in an amount between about 30 wt.% to about 99 wt.%.

17. The gel polymer electrolyte of claim 1, wherein the liquid electrolyte is present in an amount of about 95 wt.% or greater.

18. A gellable electrolyte for a rechargeable battery comprising (i) a liquid gelling agent mixture of (A) an amine-group containing material, (B) a halide-group or epoxy-group containing material, and (ii) a liquid

electrolyte which contains an amount of an ionic salt effective to achieve ionic conductivity of about  $1 \times 10^{-2}$  S/cm or less.

19. The gellable electrolyte as in claim 18, wherein the halide-group containing material includes at least one halide group selected from chlorides, bromides and iodides.

20. The gellable electrolyte as in claim 18, wherein the epoxy-group containing material includes at least one monomer, oligomer or polymer having at least one epoxy unit.

21. The gellable electrolyte as in claim 18, wherein the ionic salt is a lithium salt.

22. The gellable electrolyte as in claim 21, wherein the lithium salt is at least one selected from the group consisting of  $\text{LiPF}_6$ ,  $\text{LiAsF}_6$ ,  $\text{LiClO}_4$ ,  $\text{LiN}(\text{CF}_3\text{SO}_2)_2$ ,  $\text{LiBF}_4$ ,  $\text{LiCF}_3\text{SO}_3$  and  $\text{LiSbF}_6$ .

23. The gellable electrolyte as in claim 18, wherein the ionic salt is present in an amount effective to achieve an ionic conductivity of between about  $1 \times 10^{-3}$  to about  $1 \times 10^{-2}$  S/cm.

24. The gellable electrolyte as in claim 18, wherein the nitrogen-group containing material (A) includes at least one secondary or tertiary amine selected from polymers, copolymers, oligomers and monomers containing 6- membered aromatic heterocycles, 5-membered fused aromatic heterocycles and aromatic or non-aromatic tertiary amine compounds.

25. The gellable electrolyte as in claim 24, wherein the material (A) includes at least one compound selected from the group consisting of pyridines, pyridazines, pyrimidines, pyrazines, triazines, triazoles, thiazoles, thiadiazoles, and compounds containing five or more carbon atoms in addition to at least one nitrogen atom.

26. The gellable electrolyte as in claim 18 or 25, wherein material (B) includes an epoxy-group containing material and/or an aromatic or non-aromatic halide material.

27. The gellable electrolyte as in claim 26, wherein the material (B) is an aromatic halide selected from polymers, copolymers or monomers containing halomethyl benzene, halomethyl naphthalene, halomethyl biphenyl, bis(halomethyl) benzene, bis(halomethyl) naphthalene, bis(halomethyl) biphenyl, tris(halomethyl) benzene, tris(halomethyl) naphthalene, tris(halomethyl) biphenyl, tetrakis(halomethyl) benzene, tetrakis(halomethyl) naphthalene, tetrakis(halomethyl) biphenyl, halomethylstyrene.

28. The gellable electrolyte of claim 27, wherein the halomethyl of the aromatic halide is chloromethyl, bromomethyl or iodomethyl.

29. The gel polymer of claim 26, wherein the material (B) is a non-aromatic halide selected from C2 or greater alkanes which include diiodo, triiodo or tetraiodo groups.

30. The gel polymer as in claim 26, wherein material (B) is an epoxy-group containing material which is at least one selected from the group consisting of 3,4-epoxycyclohexylmethyl-3',4'-epoxycyclohexane

carboxylate, glycidyl dodecafluoroheptylether, polypropylene glycol diglycidyl ether, glycidyl dodecafluoroheptylether, butadiene diepoxide, butanediol diglycidyl ether, cyclo hexene oxide, cyclopentene oxide, diepoxy cyclooctane, ethylene glycol diglycidyl ether and 1,2-epoxy hexane.

31. The gellable electrolyte of claim 18, wherein the gelling agent is present in an amount between about 1 wt.% to about 30 wt.%.

32. The gellable electrolyte of claim 18 or 31, wherein the liquid electrolyte is present in an amount between about 30 wt.% to about 99 wt.%.

33. The gellable electrolyte of claim 18, wherein the liquid electrolyte is present in an amount of about 95 wt.% or greater.

34. The gellable electrolyte of claim 33, wherein the ionic salt is present in an amount between about 0.5M to 2.0M.

35. A rechargeable battery comprising an anode, a cathode, a microporous separator separating said anode and said cathode, and a gel polymer electrolyte according to any one of claims 1-9.

36. The rechargeable battery of claim 35 which exhibits a pre-charge voltage of at least about 0.3 V or greater.

37. A method of making a rechargeable battery comprising the steps of:

- (1) positioning within a battery case an anode, a cathode and a separator sheet between the anode and cathode;
- (2) pouring into the battery case a gellable electrolyte comprised of (i) a gelling agent mixture of (A) an amine-group containing material, (B) a halide-group or epoxy-group containing material, and (ii) a liquid electrolyte which contains an amount of an ionic salt effective to achieve ionic conductivity of about  $1 \times 10^{-2}$  S/cm or less; and
- (3) sealing the case.

38. The method of claim 37, wherein the halide-group containing material (B) includes at least one halide group selected from chlorides, bromides and iodides.

39. The method of claim 37, wherein the epoxy-group containing material (B) includes at least one monomer, oligomer or polymer having at least one epoxy unit.

40. The method of claim 37, wherein the ionic salt is a lithium salt.

41. The method of claim 40, wherein the lithium salt is at least one selected from the group consisting of  $\text{LiPF}_6$ ,  $\text{LiAsF}_6$ ,  $\text{LiClO}_4$ ,  $\text{LiN}(\text{CF}_3\text{SO}_2)_2$ ,  $\text{LiBF}_4$ ,  $\text{LiCF}_3\text{SO}_3$  and  $\text{LiSbF}_6$ .

42. The method of any one of claims 37-41, wherein the ionic salt is present in an amount effective to achieve an ionic conductivity of between about  $1 \times 10^{-3}$  to about  $1 \times 10^{-2}$  S/cm.

43. The method of claim 37, wherein the nitrogen-group containing material (A) includes at least one secondary or tertiary amine selected from polymers, copolymers, oligomers and monomers containing 6-membered aromatic heterocycles, 5-membered fused aromatic heterocycles and aromatic or non-aromatic tertiary amine compounds.

44. The method of claim 43, wherein the material (A) includes at least one compound selected from the group consisting of pyridines, pyridazines, pyrimidines, pyrazines, triazines, triazoles, thiazoles, thiadiazoles, and compounds containing five or more carbon atoms in addition to at least one nitrogen atom.

45. The method of claim 37 or 44, wherein material (B) includes an epoxy-group containing material and/or an aromatic or non-aromatic halide material.

46. The method of claim 45, wherein the material (B) is an aromatic halide selected from polymers, copolymers or monomers containing halomethyl benzene, halomethyl naphthalene, halomethyl biphenyl, bis(halomethyl) benzene, bis(halomethyl) naphthalene, bis(halomethyl) biphenyl, tris(halomethyl) benzene, tris(halomethyl) naphthalene, tris(halomethyl) biphenyl, tetrakis(halomethyl) benzene, tetrakis(halomethyl) naphthalene, tetrakis(halomethyl) biphenyl, halomethylstyrene.

47. The method of claim 46, wherein the halomethyl of the aromatic halide is chloromethyl, bromomethyl or iodomethyl.



48. The method of claim 45, wherein the material (B) is a non-aromatic halide selected from C2 or greater alkanes which include diiodo, triiodo or tetraiodo groups.

49. The method of claim 45, wherein material (B) is an epoxy-group containing material which is at least one selected from the group consisting of 3,4-epoxycyclohexylmethyl-3',4'-epoxycyclohexane carboxylate, glycidyl dodecafluoroheptylether, polypropylene glycol diglycidyl ether, glycidyl dodecafluoroheptylether, butadiene diepoxide, butanediol diglycidyl ether, cyclo hexene oxide, cyclopentene oxide, diepoxy cyclooctane, ethylene glycol diglycidyl ether and 1,2-epoxy hexane.

50. The method of claim 37, wherein the gelling agent is present in an amount between about 1 wt.% to about 30 wt.% in a gellable electrolyte.

51. The method of claim 37 or 50, wherein the liquid electrolyte is present in an amount between about 30 wt.% to about 99 wt.% in a gellable electrolyte.

52. The method of claim 37, wherein the liquid electrolyte is present in an amount of about 95 wt.% or greater.

53. The method of claim 37, wherein the ionic salt is present in an amount between about 0.5M to 2.0M in a gellable electrolyte.

54. The method of claim 37, wherein the anode includes an active carbonaceous material.

55. The method of any one of claims 37-40, further comprising the step of:

- (4)     subjecting the sealed case to elevated temperature  
          for a time sufficient for the gellable electrolyte  
          therewithin to form a gel polymer electrolyte in situ.

56. The method of claim 55, wherein step (4) is practiced at a temperature of between about 30°C to about 130°C.

57. The method of claim 56, wherein the anode includes an active carbonaceous material.

58. The method of claim 37, wherein the additive is a primary, secondary or tertiary amine capable of capturing hydrogen fluorides or Lewis acids.

59. The method of claim 37, wherein the additive is present in an amount between about 0.01 wt.% to about 5 wt.%

60. The method of claim 37, wherein step (2) is practiced such that the rechargeable battery exhibits a pre-charge voltage of at least about 0.3 V or greater.

61. The method of claim 37, wherein the liquid electrolyte is present in an amount between about 95 wt.% to about 99.99 wt.%.